

## ***Relativistic Nuclear Collision Program Overview***

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### **Introduction**

The Relativistic Nuclear Collisions Program (RNC) at LBNL conducts experiments which study the collisions of nuclei over a large energy range. At Bevalac energies nuclear matter is compressed sufficiently to study its equation of state. At the AGS at Brookhaven National Laboratory (BNL), these studies were extended to an energy range where the maximum pressure from the baryons is likely to occur. At the CERN-SPS the energy density of the system created in a collision of very heavy nuclei may be sufficient to produce a phase transition to a plasma of free quarks and gluons, whereas at the Relativistic Heavy Ion Collider (RHIC) the energy density is expected to be sufficiently high that production of the Quark-Gluon Plasma (QGP) should occur. At lower energies (Bevalac, AGS) one attempts to determine the equation of state of nuclear matter. However, the main goal of the current program is to excite the QCD ground state (vacuum) over a macroscopic volume in order to study its properties. The conceptual questions to be addressed are: What is the phase structure of QCD? Is there a phase transition to a QGP? Is there a chiral phase transition? Are the chiral and the QGP phase transition identical? What is the origin of the mass of the light hadrons? What are the properties of the chiral/QGP phase? Understanding those questions is of fundamental interest and is a central part of the U.S. Nuclear Science Long Range Plan.

RNC scientists recently completed the analysis of data from two large experiments, E895 at the AGS and NA49 at the CERN SPS. Both experiments have produced a wealth of data and numerous publications. The main focus of the high-energy heavy-ion research program at LBNL is the analysis of the STAR experiment at RHIC, which had an extremely successful data taking run in the summer of 2000.

### **STAR**

STAR is a collider experiment at RHIC designed to study Au-Au collisions at a nucleon-nucleon center of mass energy of 200 GeV. As in NA49, the goal is to simultaneously measure many hadronic signals that might indicate a phase change due to the increased number of degrees of freedom. To perform event-by-event analysis, almost all charged particles over two units of rapidity, centered at mid-rapidity will be measured and identified. Study of soft particle production and correlations, including flow, will allow us to understand the space-time evolution of the source and to learn about early pressure. Photons and neutral mesons will also be measured with this detector. At RHIC energies there is a high rate of hard processes. Hard-scattered partons are predicted to be sensitive to the medium through which they propagate. The process can be calculated in perturbative quantum chromodynamics. The study of high transverse momentum particles and jets as a function of energy and mass of the colliding system may also be an attractive experimental approach to identify the presence of quark-gluon matter.

LBNL's RNC Program is providing the focus for many STAR activities. Within the STAR organization, the RNC program has provided the project leadership, the engineering management and overall detector integration, as well as building a large fraction of the hardware. RNC has primary responsibility for the time projection chamber (TPC) and its electronics. This is the core and the *raison d'être* for STAR. RNC also has significant responsibilities within the software efforts in STAR. RNC physicists form the core of the software development team that is focused on tracking and particle identification in the TPC.

Analysis of the data from the first round of Au+Au collisions at 130 AGeV is progressing swiftly. A systematic study of the elliptic flow ( $v_2$ ) shows that at RHIC energies the elliptic flow is compatible with the behavior expected from models that assume local thermal equilibrium (hydrodynamics). These results were published in Physical Review Letters in January 2001. An extensive effort to extract spectra and particle ratios of produced particles is also under way.

The RNC Program has broadened its physics base by starting the peripheral collisions physics program within STAR. For heavy ions at RHIC the luminosity for photon-photon interactions in peripheral collisions is very high so that an extensive program of meson spectroscopy becomes possible. At the same time Pomeron-Pomeron interactions and photon-Pomeron interactions, both of fundamental importance, can be investigated.

The analysis of collisions of polarized protons in the STAR detector is an important part of the STAR physics program. The goal of the program is to measure the polarized proton structure function  $DG$ . The RNC Program is planning to participate in the SPIN physics program of STAR. We are also considering a modest participation in the ALICE experiment at LHC.

Analyzing the large amount of data accumulated with the STAR detector is a formidable challenge. New concepts for data handling and storage are needed and are being developed. The Grand Challenge Initiative has led to improved data management for RHIC computing. The STAR data analysis center at LBNL that is operated by NERSC is being used widely by a large number of STAR collaborators and is close to planned capacity.

We have always been involved in detector development at the leading edge of technology. New detector technologies have enabled us to make better and more precise measurements in the past. One of the challenges for the STAR detector is to improve the vertex resolution in order to enable the measurement of D-mesons. We have started the development of a novel high resolution vertex detector based on CMOS technology.